BRITISH STANDARD

BS ISO 80000-10:2009

Quantities and units

Part 10: Atomic and nuclear physics

ICS 01.060

British Standards

National foreword

This British Standard is the UK implementation of ISO 80000-10:2009. It supersedes BS ISO 31-10:1992 and BS ISO 31-9:1992 which are withdrawn.

The UK participation in its preparation was entrusted to Technical Committee SS/7, General metrology, quantities, units and symbols.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 January 2010

ISBN 978 0 580 54870 3

Amendments/corrigenda issued since publication

Date	Comments

INTERNATIONAL STANDARD

ISO 80000-10

First edition
2009-12-01

Quantities and units —

Part 10: **Atomic and nuclear physics**

Grandeurs et unités —

Partie 10: Physique atomique et nucléaire

Reference number
ISO 80000-10:2009(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for whom a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 80000-10 was prepared by Technical Committee ISO/TC 12, *Quantities and units,* in co-operation with IEC/TC 25, *Quantities and units*.

This first edition of ISO 80000-10 cancels and replaces ISO 31-9:1992 and ISO 31-10:1992. It also incorporates Amendments ISO 31-9:1992/Amd.1:1998 and ISO 31-10:1992/Amd.1:1998. The major technical changes from the previous standards are the following:

— Annex A and Annex B to ISO 31-9:1992 have been deleted (as they are covered by ISO 80000-9);

— Annex C to ISO 31-9:1992 has become Annex A;

— Annex D to ISO 31-9:1992 has been deleted;

— the presentation of numerical statements has been changed;

— the *Normative references* have been changed;

— items 10-33 and 10-53 from ISO 31-10:1992 have been deleted;

— new items have been added;

— many definitions have been re-formulated;

— newer values for fundamental constants have been used.

ISO 80000 consists of the following parts, under the general title *Quantities and units*:

— *Part 1: General*

— *Part 2: Mathematical signs and symbols to be used in the natural sciences and technology*

— *Part 3: Space and time*

— *Part 4: Mechanics*

— *Part 5: Thermodynamics*

— *Part 7: Light*

— *Part 8: Acoustics*

— *Part 9: Physical chemistry and molecular physics*

— *Part 10: Atomic and nuclear physics*

— *Part 11: Characteristic numbers*

— *Part 12: Solid state physics*

IEC 80000 consists of the following parts, under the general title *Quantities and units*:

— *Part 6: Electromagnetism*

— *Part 13: Information science and technology*

— *Part 14: Telebiometrics related to human physiology*

Introduction

0.1 Arrangements of the tables

The tables of quantities and units in this International Standard are arranged so that the quantities are presented on the left-hand pages and the units on the corresponding right-hand pages.

All units between two full lines on the right-hand pages belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of an item has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parenthesis on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

0.2 Tables of quantities

The names in English and in French of the most important quantities within the field of this International Standard are given together with their symbols and, in most cases, their definitions. These names and symbols are recommendations. The definitions are given for identification of the quantities in the International System of Quantities (ISQ), listed on the left hand pages of the table; they are not intended to be complete.

The scalar, vector or tensor character of quantities is pointed out, especially when this is needed for the definitions.

In most cases only one name and only one symbol for the quantity are given; where two or more names or two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing. When two types of italic letters exist (for example as with ϑ and θ; φ and ϕ; *a* and a; *g* and g), only one of these is given. This does not mean that the other is not equally acceptable. It is recommended that such variants not be given different meanings. A symbol within parentheses implies that it is a reserve symbol, to be used when, in a particular context, the main symbol is in use with a different meaning.

In this English edition, the quantity names in French are printed in an italic font, and are preceded by *fr*. The gender of the French name is indicated by (m) for masculine and (f) for feminine, immediately after the noun in the French name.

0.3 Tables of units

0.3.1 General

The names of units for the corresponding quantities are given together with the international symbols and the definitions. These unit names are language-dependent, but the symbols are international and the same in all languages. For further information, see the SI Brochure (8th edition, 2006) from BIPM and ISO 80000-1.

The units are arranged in the following way:

a) The coherent SI units are given first. The SI units have been adopted by the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures, CGPM). The coherent SI units and their decimal multiples and submultiples formed with the SI prefixes are recommended, although the decimal multiples and submultiples are not explicitly mentioned.

b) Some non-SI units are then given, namely those accepted by the International Committee for Weights and Measures (Comité International des Poids et Mesures, CIPM), or by the International Organization of Legal Metrology (Organisation Internationale de Métrologie Légale, OIML), or by ISO and IEC, for use with the SI.

   Such units are separated from the SI units in the item by use of a broken line between the SI units and the other units.

c) Non-SI units currently accepted by the CIPM for use with the SI are given in small print (smaller than the text size) in the "Conversion factors and remarks" column.

d) Non-SI units that are not recommended are given only in annexes in some parts of this International Standard. These annexes are informative, in the first place for the conversion factors, and are not integral parts of the standard. These deprecated units are arranged in two groups:

   1) units in the CGS system with special names;

   2) units based on the foot, pound, second, and some other related units.

e) Other non-SI units given for information, especially regarding the conversion factors, are given in informative annexes in some parts of this International Standard.

0.3.2 Remark on units for quantities of dimension one, or dimensionless quantities

The coherent unit for any quantity of dimension one, also called a dimensionless quantity, is the number one, symbol 1. When the value of such a quantity is expressed, the unit symbol 1 is generally not written out explicitly.

EXAMPLE 1 Refractive index $n = 1{,}53 \times 1 = 1{,}53$

Prefixes shall not be used to form multiples or submultiples of this unit. Instead of prefixes, powers of 10 are recommended.

EXAMPLE 2 Reynolds number $Re = 1{,}32 \times 10^3$

Considering that the plane angle is generally expressed as the ratio of two lengths and the solid angle as the ratio of two areas, in 1995 the CGPM specified that, in the SI, the radian, symbol rad, and steradian, symbol sr, are dimensionless derived units. This implies that the quantities plane angle and solid angle are considered as derived quantities of dimension one. The units radian and steradian are thus equal to one; they may either be omitted, or they may be used in expressions for derived units to facilitate distinction between quantities of different kind but having the same dimension.

0.4 Numerical statements in this International Standard

The sign $=$ is used to denote "is exactly equal to", the sign $\approx$ is used to denote "is approximately equal to", and the sign $:=$ is used to denote "is by definition equal to".

Numerical values of physical quantities that have been experimentally determined always have an associated measurement uncertainty. This uncertainty should always be specified. In this International Standard, the magnitude of the uncertainty is represented as in the following example.

EXAMPLE $l = 2{,}347\ 82(32)$ m

In this example, $l = a(b)$ m, the numerical value of the uncertainty b indicated in parentheses is assumed to apply to the last (and least significant) digits of the numerical value a of the length l. This notation is used when b represents the standard uncertainty (estimated standard deviation) in the last digits of a. The numerical example given above may be interpreted to mean that the best estimate of the numerical value of the length l, when l is expressed in the unit metre is 2,347 82, and that the unknown value of l is believed to

lie between (2,347 82 – 0,000 32) m and (2,347 82 + 0,000 32) m with a probability determined by the standard uncertainty 0,000 32 m and the probability distribution of the values of l.

0.5 Special remarks

0.5.1 Quantities

The fundamental physical constants given in ISO 80000-10 are quoted in the consistent values of the fundamental physical constants published in "2006 CODATA recommended values". See the CODATA website: http://physics.nist.gov/cuu/constants/index.html.

0.5.2 Special units

Individual scientists should have the freedom to use non-SI units when they see a particular scientific advantage in their work. For this reason, non-SI units which are relevant for atomic and nuclear physics are listed in Annex A.

Quantities and units —

Part 10: Atomic and nuclear physics

1 Scope

ISO 80000-10 gives the names, symbols, and definitions for quantities and units used in atomic and nuclear physics. Where appropriate, conversion factors are also given.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 80000-3:2006, *Quantities and units — Part 3: Space and time*

ISO 80000-4:2006, *Quantities and units — Part 4: Mechanics*

ISO 80000-5:2007, *Quantities and units — Part 5: Thermodynamics*

IEC 80000-6:2008, *Quantities and units — Part 6: Electromagnetism*

ISO 80000-7:2008, *Quantities and units — Part 7: Light*

ISO 80000-9:2009, *Quantities and units — Part 9: Physical chemistry and molecular physics*

3 Names, symbols, and definitions

The names, symbols, and definitions for quantities and units used in atomic and nuclear physics are given on the following pages.

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-1.1 (*9-1*)	atomic number, proton number *fr* *numéro* (m) *atomique*, *nombre* (m) *de protons*	Z	number of protons in an atomic nucleus	A nuclide is a species of atom with specified numbers of protons and neutrons. Nuclides with the same value of Z but different values of N are called isotopes of an element. The ordinal number of an element in the periodic table is equal to the atomic number. The atomic number equals the charge of the nucleus in units of the elementary charge (item 10-5.1).
10-1.2 (*9-2*)	neutron number *fr* *nombre* (m) *de neutrons*	N	number of neutrons in an atomic nucleus	Nuclides with the same value of N but different values of Z are called isotones. $N - Z$ is called the neutron excess number.
10-1.3 (*9-3*)	nucleon number, mass number *fr* *nombre* (m) *de nucléons*, *nombre* (m) *de masse*	A	number of nucleons in an atomic nucleus	$A = Z + N$ Nuclides with the same value of A are called isobars.
10-2 (*9-5.1*) (*9-5.2*) (*9-5.3*)	rest mass, proper mass *fr* *masse* (f) *au repos*, *masse* (f) *propre*	$m(\mathrm{X})$, m_X	for particle X, mass (ISO 80000-4:2006, item 4-1) of that particle at rest	Specifically, for an electron: $m_\mathrm{e} = 9{,}109\ 382\ 15(45) \times 10^{-31}$ kg; for a proton: $m_\mathrm{p} = 1{,}672\ 621\ 637(83) \times 10^{-27}$ kg; for a neutron: $m_\mathrm{n} = 1{,}674\ 927\ 211(84) \times 10^{-27}$ kg [2006 CODATA recommended values]. Rest mass is often denoted m_0.
10-3 (—)	rest energy *fr* *énergie* (f) *au repos*	E_0	for a particle, $E_0 = m_0 c_0^2$ where m_0 is the rest mass (item 10-2) of that particle, and c_0 is the speed of light in vacuum (ISO 80000-7:2008, item 7-4.1)	

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-1.a	one	1		See the Introduction, 0.3.2.
10-2.a	kilogram	kg		
10-2.b	dalton, unified atomic mass unit	Da u	1 dalton is equal to 1/12 times the mass of a free carbon 12 atom, at rest and in its ground state	1 Da = 1 u = 1,660 538 782(83) × 10^{-27} kg [2006 CODATA recommended values].
10-3.a	joule	J		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-4.1 (*9-4.1*)	atomic mass, nuclidic mass *fr* *masse* (f) *atomique*, *masse* (f) *nucléidique*	$m(\mathrm{X})$, m_a	rest mass (ISO 80000-4:2006, item 4-1) of a neutral atom or a nuclide X in the ground state	$\frac{m_\mathrm{a}}{m_\mathrm{u}}$ is called the relative atomic mass.
10-4.2 (*9-4.2*)	unified atomic mass constant *fr* *constante* (f) *unifiée de masse atomique*	m_u	1/12 of the mass (ISO 80000-4:2006, item 4-1) of a neutral atom of the nuclide $^{12}\mathrm{C}$ in the ground state at rest	$m_\mathrm{u} = 1{,}660\ 538\ 782(83) \times 10^{-27}$ kg [2006 CODATA recommended values].
10-5.1 (*9-6*)	elementary charge *fr* *charge* (f) *élémentaire*	e	negative of electric charge (IEC 80000-6:2008, item 6-2) of the electron	$e = 1{,}602\ 176\ 487(40) \times 10^{-19}$ C [2006 CODATA recommended values].
10-5.2 (—)	charge number, ionization number *fr* *nombre* (m) *de charge*, *charge* (f) *ionique*	c	for a particle, the electric charge (IEC 80000-6:2008, item 6-2) divided by the elementary charge (item 10-5.1)	A particle is said to be electrically neutral if its charge number is equal to zero. The charge number of a particle can be positive, negative, or zero. The state of charge of a particle may be presented as a superscript to the symbol of that particle, e.g. H^{+}, He^{++}, Al^{3+}, Cl^{-}, $\mathrm{S}^{=}$, N^{3-}
10-6.1 (*9-7*)	Planck constant *fr* *constante* (f) *de Planck*	h	elementary quantum of action (ISO 80000-4:2006, item 4-37)	$h = 6{,}626\ 068\ 96(33) \times 10^{-34}$ J s [2006 CODATA recommended values]. Energy E of harmonic vibration of frequency f can change for multiples of $\Delta E = hf = \hbar\omega$ only.
10-6.2 (—)	reduced Planck constant *fr* *constante* (f) *de Planck réduite*	$\hbar$	$\hbar = \frac{h}{2\pi}$ where h is the Planck constant (item 10-6.1)	$\hbar = 1{,}054\ 571\ 628(53) \times 10^{-34}$ J s [2006 CODATA recommended values]. $\hbar$ is sometimes known as hbar or the Dirac constant.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-4.a	kilogram	kg		
10-4.b	dalton, unified atomic mass unit	Da, u	1 dalton is equal to 1/12 times the mass of a free carbon 12 atom, at rest and in its ground state	1 Da = 1 u = 1,660 538 782(83) × 10^{-27} kg [2006 CODATA recommended values].
10-5.a	coulomb	C		
10-6.a	joule second	J · s		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-7 (*9-8*)	Bohr radius *fr rayon* (m) *de Bohr*	a_0	$a_0 = \frac{4\pi\varepsilon_0 \hbar^2}{m_e e^2}$ where ε_0 is the electric constant (IEC 80000-6:2008, item 6-14.1), $\hbar$ is the reduced Planck constant (item 10-6.2), m_e is the rest mass of electron (item 10-2), and e is the elementary charge (item 10-5.1)	$a_0 = 0{,}529\ 177\ 208\ 59(36) \times 10^{-10}$ m [2006 CODATA recommended values]. The radius of the electron orbital in the H-atom in its ground state is a_0 in the Bohr model of the atom.
10-8 (*9-9*)	Rydberg constant *fr constante* (f) *de Rydberg*	R_∞	$R_\infty = \frac{e^2}{8\pi\varepsilon_0 a_0 h c_0}$ where e is the elementary charge (item 10-5.1), ε_0 is the electric constant (IEC 80000-6:2008, item 6-14.1), a_0 is the Bohr radius (item 10-7), h is the Planck constant (item 10-6.1), and c_0 is the speed of light in vacuum (ISO 80000-7:2008, item 7-4.1)	$R_\infty =$ 10 973 731,568 527(73) m^{-1} [2006 CODATA recommended values] The quantity $R_y = R_\infty \cdot hc_0$ is called Rydberg energy.
10-9 (*9-10*)	Hartree energy *fr énergie* (f) *de Hartree*	E_H, E_h	$E_H = \frac{e^2}{4\pi\varepsilon_0 a_0}$ where e is the elementary charge (item 10-5.1), ε_0 is the electric constant (IEC 80000-6:2008, item 6-14.1), and a_0 is the Bohr radius (item 10-7)	$E_H = 4{,}359\ 743\ 94(22) \times 10^{-18}$ J [2006 CODATA recommended values]. The energy of the electron in H-atom in its ground state is $-E_H$. $E_H = 2R_\infty \cdot hc_0$.

UNITS				ATOMIC AND NUCLEAR PHYSICS
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-7.a	metre	m		ångström (Å), 1 Å := 10^{-10} m
10-8.a	metre to the power minus one	m^{-1}		
10-9.a	joule	J		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-10.1 (*9-11.1*)	magnetic dipole moment *fr* *moment* (m) *magnétique*	$\boldsymbol{\mu}$	for a particle or nucleus, vector quantity causing an increment $\Delta W = -\boldsymbol{\mu} \cdot \boldsymbol{B}$ to its energy W (ISO 80000-5:2007, item 5-20.1) in an external magnetic field with magnetic flux density $\boldsymbol{B}$ (IEC 80000-6:2008, item 6-21)	For an atom or nucleus, this energy is quantized and may be written as $W = g\mu_X MB$ where g is the appropriate g-factor (item 10-15.1 or item 10-15.2), μ_X is mostly the Bohr magneton or nuclear magneton (item 10-10.2 or item 10-10.3), M is the magnetic quantum number (item 10-14.4), and B is the magnitude of the magnetic flux density. See also IEC 80000-6:2008, item 6-23.
10-10.2 (*9-11.2*)	Bohr magneton *fr* *magnéton* (m) *de Bohr*	μ_B	$\mu_B = \frac{e\hbar}{2m_e}$ where e is the elementary charge (item 10-5.1), and m_e is the rest mass of electron (item 10-2)	$\mu_B = 927{,}400\ 915(23) \times 10^{-26}$ J T^{-1} [2006 CODATA recommended values]. μ_B is magnetic moment of an electron in a state with orbital quantum number $l = 1$ (item 10-14.3) due to its orbital motion.
10-10.3 (*9-11.3*)	nuclear magneton *fr* *magnéton* (m) *nucléaire*	μ_N	$\mu_N = \frac{e\hbar}{2m_p}$ where e is the elementary charge (item 10-5.1), and m_p is the rest mass of proton (item 10-2)	$\mu_N = 5{,}050\ 783\ 24(13) \times 10^{-27}$ J T^{-1} [2006 CODATA recommended values]. Subscript N stands for nucleus. For the neutron magnetic moment, subscript n is used. The magnetic moments of protons or neutrons differ from this quantity by their specific g-factors (item 10-15.2).
10-11 (—)	spin *fr* *spin* (m)	$\boldsymbol{s}$	internal angular momentum (ISO 80000-4:2006, item 4-12) of a particle or a particle system	Spin is an additive vector quantity.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-10.a	ampere square metre	$A \cdot m^2$		
10-11.a	kilogram metre squared per second	$kg \cdot m^2 \cdot s^{-1}$		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-12 (—)	total angular momentum *fr moment* (m) *cinétique total*	$\boldsymbol{J}$	vector quantity in a quantum microsystem composed of angular momentum $\boldsymbol{\Lambda}$ (ISO 80000-4:2006, item 4-12) and spin $\boldsymbol{s}$ (item 10-11)	In atomic and nuclear physics, orbital angular momentum is usually denoted by $\boldsymbol{l}$ or $\boldsymbol{L}$ instead of $\boldsymbol{\Lambda}$. The magnitude of $\boldsymbol{J}$ is quantized so that $J^2 = \hbar^2 j(j+1)$, where j is the total angular momentum quantum number (item 10-14.6). Total angular momentum and magnetic dipole moment have the same direction. j is not the magnitude of the total angular momentum $\boldsymbol{J}$ but its projection onto the quantization axis, divided by $\hbar$.
10-13.1 (*9-12*)	gyromagnetic ratio for electron, magnetogyric ratio for electron, gyromagnetic coefficient for electron *fr coefficient* (m) *gyro-magnétique de l'électron*	γ_e	$\boldsymbol{\mu} = \gamma_e \boldsymbol{J}$ where $\boldsymbol{\mu}$ is the magnetic dipole moment (item 10-10.1), and $\boldsymbol{J}$ is the total angular momentum (item 10-12)	
10-13.2 (*9-12*)	gyromagnetic ratio, magnetogyric ratio, gyromagnetic coefficient *fr coefficient* (m) *gyro-magnétique*	γ	$\boldsymbol{\mu} = \gamma \boldsymbol{J}$ where $\boldsymbol{\mu}$ is the magnetic dipole moment (item 10-10.1), and $\boldsymbol{J}$ is the total angular momentum (item 10-12)	The systematic name is “gyromagnetic coefficient”, but “gyromagnetic ratio” is more usual. The gyromagnetic ratio of the proton is denoted by γ_p. $\gamma_p = 2{,}675\ 222\ 099(70) \times 10^8\ \mathrm{s}^{-1}\ \mathrm{T}^{-1}$ [2006 CODATA recommended values].

UNITS				ATOMIC AND NUCLEAR PHYSICS
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-12.a	joule second	$J \cdot s$		
10-13.a	ampere square metre per joule second	$A \cdot m^2/(J \cdot s)$		$1\ A \cdot m^2/(J \cdot s) = 1\ A \cdot s/kg = 1\ T^{-1} \cdot s^{-1}$

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-14.1 (—)	quantum number *fr* *nombre* (m) *quantique*	n, l, m, j, s, F	number describing particular state of a quantum microsystem	Electron states determine the binding energy $E = E(n, m, j, s)$ in an atom. Capitals L, M, J, S are usually used for the whole system. The spatial probability distribution of an electron is given by $\vert\psi\vert^2$ where ψ is its wave function. For an electron in an H-atom in a non-relativistic approximation, it can be presented as $\psi(r, \vartheta, \varphi) = R_{nl}(r) \cdot \mathrm{Y}_l^m(\vartheta, \varphi)$ where r, ϑ, φ are spherical coordinates (ISO 80000-2:2009, item 2-16.3) with respect to the nucleus and to a given (quantization) axis, $R_{nl}(r)$ is the radial distribution function and $\mathrm{Y}_l^m(\vartheta, \varphi)$ are spherical harmonics. In the Bohr model of one-electron atoms, n, l and m define the possible orbits of an electron around the nucleus.
10-14.2 (9-23)	principal quantum number *fr* *nombre* (m) *quantique principal*	n	atomic quantum number related to the number $n-1$ of radial nodes of one-electron wave functions	In the Bohr model, $n = 1, 2, \ldots, \infty$ is related to the binding energy of an electron and the radius of spherical orbits (principal axis of the elliptic orbits). For an electron in an H-atom, the semi-classical radius of its orbit is $r_n = a_0 n^2$ and its binding energy is $E_n = E_\mathrm{H} / n^2$.
10-14.3 (9-18)	orbital angular momentum quantum number *fr* *nombre* (m) *quantique du moment cinétique orbital*, *nombre* (m) *quantique orbital*	l, l_i, L	atomic quantum number related to the orbital angular momentum l of a one-electron state	$l^2 = \hbar^2 l(l+1)$, $l = 0, 1, \ldots, n-1$. l_i refers to a specific particle i; L is used for the whole system. An electron in an H-atom for $l = 0$ appears as a spherical cloud. In the Bohr model, it is related to the form of the orbit.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-14.a	one	1		See the Introduction, 0.3.2.

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-14.4 (9-24)	magnetic quantum number *fr* *nombre* (m) *quantique magnétique*	m, m_i, M	atomic quantum numbers related to the the z-component l_z, j_z or s_z of the orbital, total or spin angular momentum	$l_z = m_l \hbar$, $j_z = m_j \hbar$, $s_z = m_s \hbar$ with the ranges from $-l$ to l, from $-j$ to j, and ±1/2, respectively. m_i refers to a specific particle i; M is used for the whole system. Subscripts l, s, j, etc., as appropriate, indicate the angular momentum involved.
10-14.5 (9-19)	spin quantum number *fr* *nombre* (m) *quantique du spin*	s	characteristic quantum number of a particle, related to its spin angular momentum $\boldsymbol{s}$: $\boldsymbol{s}^2 = \hbar^2 s(s+1)$	Fermions have $s = 1/2$ or $s = 3/2$. Observed bosons have $s = 0$ or $s = 1$. The total spin quantum number S of an atom is related to the total spin (angular momentum), which is the sum of the spins of the electrons. It has the possible values $S = 0, 1, 2, \ldots$ for even Z and $S = \frac{1}{2}, \frac{3}{2}, \ldots$ for odd Z.
10-14.6 (9-20)	total angular momentum quantum number *fr* *nombre* (m) *quantique du moment cinétique total*	j, j_i, J	quantum number in an atom describing magnitude of total angular momentum $\boldsymbol{J}$ (item 10-12)	j_i refers to a specific particle i; J is used for the whole system. Care has to be taken, as quantum number J is not the magnitude of total angular momentum $\boldsymbol{J}$ (item 10-12). The two values of j are $l \pm 1/2$. (See item 10-14.3.) Here, “total” does not mean “complete”.
10-14.7 (9-21)	nuclear spin quantum number *fr* *nombre* (m) *quantique de spin nucléaire*	I	quantum number related to the total angular momentum J of a nucleus in any specified state, normally called nuclear spin: $I^2 = \hbar^2 I(I+1)$	Nuclear spin is composed of spins of the nucleons (protons and neutrons) and their (orbital) motions. In principle there is no upper limit for the nuclear spin quantum number. It has possible values $I = 0, 1, 2 \ldots$ for even A and $I = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \ldots$ for odd A. In nuclear and particle physics, J is often used.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-14.a	one	1		See the Introduction, 0.3.2.

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-14.8 (9-22)	hyperfine structure quantum number *fr* *nombre* (m) *quantique de structure hyperfine*	F	quantum number of an atom describing inclination of the nuclear spin with respect to a quantization axis given by the magnetic field produced by the orbital electrons	The interval of F is $\lvert I-J \rvert$, $\lvert I-J \rvert+1$, ..., $I+J$. This is related to the hyperfine splitting of the atomic energy levels due to the interaction between the electron and nuclear magnetic moments.
10-15.1 (9-13.1)	Landé factor of atom or electron, g-factor of atom or electron *fr* *facteur* (m) *de Landé d'un atome ou d'un électron,* *facteur* (m) *g d'un atome ou d'un électron*	g	$g = \dfrac{\mu}{J\mu_B}$ where μ is magnitude of magnetic dipole moment (item 10-10.1), J is total angular momentum quantum number (item 10-14.6), and μ_B is the Bohr magneton (item 10-10.2)	These quantities are also called g-values. The Landé factor can be calculated from the expression $g(L, S, J) =$ $1 + (g_e - 1) \cdot \dfrac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}$ where $g_e = -2{,}002\ 319\ 304\ 362\ 2(15)$ is the g-factor of the electron [2006 CODATA recommended values].
10-15.2 (9-13.2)	g-factor of nucleus or nuclear particle *fr* *facteur* (m) *g d'un noyau ou d'une particule nucléaire*	g	$g = \dfrac{\mu}{I\mu_B}$ where μ is magnitude of magnetic dipole moment (item 10-10.1), I is nuclear angular momentum quantum number (item 10-14.7), and μ_B is the Bohr magneton (item 10-10.2)	The g-factors for nuclei or nucleons are known from measurements; e.g. the g-factor of the proton is $g_p = 5{,}585\ 694\ 713(46)$ [2006 CODATA recommended values].

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-14.a	one	1		See the Introduction, 0.3.2.
10-15.a	one	1		See the Introduction, 0.3.2.

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-16.1 (*9-14.1*)	Larmor angular frequency *fr pulsation* (f) *de Larmor*	ω_L	$\omega_\mathrm{L} = \frac{e}{2m_\mathrm{e}} B$ where e is the elementary charge (item 10-5.1), m_e is the rest mass of electron (item 10-2), and B is magnetic flux density (IEC 80000-6:2008, item 6-21)	The quantity $\nu_\mathrm{L} = \omega_\mathrm{L} / 2\pi$ is called the Larmor frequency.
10-16.2 (*9-14.2*)	nuclear precession angular frequency *fr pulsation* (f) *de précession nucléaire de Larmor*	ω_N	$\omega_\mathrm{N} = \gamma B$ where γ is the gyromagnetic coefficient (item 10-13.2), and B is magnetic flux density (IEC 80000-6:2008, item 6-21)	
10-17 (*9-15*)	cyclotron angular frequency *fr pulsation* (f) *cyclotron*	ω_c	$\omega_\mathrm{c} = \frac{\lvert q \rvert}{m} B$ where q is electric charge (IEC 80000-6:2008, item 6-2) of the particle, m is its mass (ISO 80000-4:2006, item 4-1), and B is the magnitude of the magnetic flux density (IEC 80000-6:2008, item 6-21)	The quantity $\nu_\mathrm{c} = \omega_\mathrm{c} / 2\pi$ is called the cyclotron frequency.
10-18 (*9-16*)	nuclear quadrupole moment *fr moment* (m) *quadripolaire nucléaire*	Q	$Q = (1/e)\int (3z^2 - r^2)\rho(x,y,z)\,\mathrm{d}V$ in the quantum state with the nuclear spin in the field direction (z), where $\rho(x,y,z)$ is the nuclear electric charge density (IEC 80000-6:2008, item 6-3), e is the elementary charge (item 10-5.1), $r^2 = x^2 + y^2 + z^2$, and $\mathrm{d}V$ is the volume element $\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z$	The electric nuclear quadrupole moment is eQ. This value is equal to the z-component of the diagonalized tensor of quadrupole moment.

UNITS				ATOMIC AND NUCLEAR PHYSICS
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-16.a	radian per second	rad/s		See the Introduction, 0.3.2.
10-16.b	second to the power minus one	s^{-1}		
10-17.a	radian per second	rad/s		
10-17.b	second to the power minus one	s^{-1}		
10-18.a	metre squared	m^2		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-19 (*9-17*)	nuclear radius *fr rayon* (m) *nucléaire*	R	conventional radius of sphere in which the nuclear matter is included	This quantity is not exactly defined. It is given approximately for nuclei in their ground state only by $R = r_0 A^{1/3}$ where $r_0 \approx 1{,}2 \times 10^{-15}$ m and A is the nucleon number.
10-20 (*9-25*)	fine-structure constant *fr constante* (f) *de structure fine*	α	$\alpha = \dfrac{e^2}{4\pi\varepsilon_0 \hbar c_0}$ where e is the elementary charge (item 10-5.1), ε_0 is the electric constant (IEC 80000-6:2008, item 6-14.1), $\hbar$ is the reduced Planck constant (item 10-6.2), and c_0 is the speed of light in vacuum (ISO 80000-7:2008, item 7-4.1)	α = 1/137,035 999 679(94) [2006 CODATA recommended values]. This is a factor historically related to the change and splitting of atomic energy levels due to relativistic effects.
10-21 (*9-26*)	electron radius *fr rayon* (m) *de l'électron*	r_e	$r_e = \dfrac{e^2}{4\pi\varepsilon_0 m_e c_0^2}$ where e is the elementary charge (item 10-5.1), ε_0 is the electric constant (IEC 80000-6:2008, item 6-14.1), m_e is the rest mass of electron (item 10-2), and c_0 is the speed of light in vacuum (ISO 80000-7:2008, item 7-4.1)	This quantity corresponds to the electrostatic energy E of a charge distributed inside a sphere of radius r_e as if all the rest energy (item 10-3) of the electron were attributed to the energy of electromagnetic origin, using the relation $E = m_e c_0^2$. r_e = 2,817 940 289 4(58) × 10^{-19} m [2006 CODATA recommended values].
10-22 (9-27)	Compton wavelength *fr longueur* (f) *d'onde de Compton*	λ_C	$\lambda_C = \dfrac{h}{m c_0}$ where h is the Planck constant (item 10-6.1), m is the rest mass (item 10-2) of a particle, and c_0 is the speed of light in vacuum (ISO 80000-7:2008, item 7-4.1)	The wavelength of electromagnetic radiation scattered from free electrons (Compton scattering) is larger than that of the incident radiation by a maximum of $2\lambda_C$.

UNITS				ATOMIC AND NUCLEAR PHYSICS
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-19.a	metre	m		Nuclear radius is usually expressed in femtometres. 1 fm = 10^{-15} m.
10-20.a	one	1		See the Introduction, 0.3.2.
10-21.a	metre	m		
10-22.a	metre	m		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-23.1 (*9-28.1*)	mass excess *fr* *excès* (m) *de masse*	Δ	$\Delta = m_a - Am_u$ where m_a is the rest mass (item 10-2) of the atom, A is its nucleon number (item 10-1.3), and m_u is the unified atomic mass constant (item 10-4.2)	
10-23.2 (*9-28.2*)	mass defect *fr* *défaut* (m) *de masse*	B	$B = Zm(^1\text{H}) + Nm_n - m_a$ where Z is the proton number (item 10-1.1) of the atom, $m(^1\text{H})$ is atomic mass (item 10-4.1) of ^1H, N is neutron number (item 10-1.2), m_n is the rest mass (item 10-2) of the neutron, and m_a is the rest mass (item 10-2) of the atom	If the binding energy of the atomic electrons is neglected, Bc_0^2 is equal to the binding energy of the nucleus.
10-24.1 (*9-29.1*)	relative mass excess *fr* *excès* (m) *de masse relatif*	Δ_r	$\Delta_r = \Delta / m_u$ where Δ is the mass excess (item 10-23.1) and m_u is the unified atomic mass constant (item 10-4.2)	
10-24.2 (*9-29.2*)	relative mass defect *fr* *défaut* (m) *de masse relatif*	B_r	$B_r = B / m_u$ where B is the mass defect (item 10-23.2) and m_u is the unified atomic mass constant (item 10-4.2)	
10-25.1 (9-30.1)	packing fraction *fr* *facteur* (m) *de tassement*	f	$f = \Delta_r / A$ where Δ_r is relative mass excess (item 10-24.1) and A is the nucleon number (item 10-1.3)	
10-25.2 (9-30.2)	binding fraction *fr* *facteur* (m) *de liaison*	b	$b = B_r / A$ where B_r is relative mass defect (item 10-24.2) and A is the nucleon number (item 10-1.3)	

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-23.a	kilogram	kg		
10-23.b	dalton, unified atomic mass unit	Da, u	See item 10-2.b.	1 Da = 1 u = 1,660 538 782(83) $\times$ 10^{-27} kg [2006 CODATA recommended values]. Quantities 10-23.1 and 10-23.2 are usually expressed in daltons.
10-24.a	one	1		See the Introduction, 0.3.2.
10-25.a	one	1		See the Introduction, 0.3.2.

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-26 (*9-36*)	decay constant, disintegration constant *fr constante* (f) *de désintégration, constante* (f) *de décroissance*	λ	relative variation $\mathrm{d}N/N$ of the number N of atoms or nuclei in a system, due to spontaneous emission from these atoms or nuclei during an infinitesimal time interval, divided by its duration $\mathrm{d}t$ (ISO 80000-3:2006, item 3-7), thus $\lambda = -\frac{1}{N}\frac{\mathrm{d}N}{\mathrm{d}t}$	For exponential decay, this quantity is constant. If more decay channels occur, then $\lambda = \sum \lambda_a$ where λ_a denotes the probability of decay to a specified final state and the sum is taken over all final states. Further, $\lambda = \frac{1}{\tau}$.
10-27 (*9-31*)	mean lifetime, mean life *fr vie* (f) *moyenne*	τ	$\tau = \frac{1}{\lambda}$ where λ is the decay constant (item 10-26)	Mean lifetime is the expectation of the lifetime of an unstable particle or an excited state of a particle.
10-28 (*9-32*)	level width *fr largeur* (f) *de niveau*	Γ	$\Gamma = \frac{\hbar}{\tau}$ where $\hbar$ is the reduced Planck constant (item 10-6.2) and τ is the mean lifetime (item 10-27)	Level width is the uncertainty of the energy of an unstable particle or an excited state of a system due to the Heisenberg principle.
10-29 (*9-33*) (*10-49*)	activity *fr activité* (f)	A	variation $\mathrm{d}N$ of spontaneous number of nuclei N in a particular energy state, in a sample of a radionuclide, due to spontaneous nuclear transitions from this state during an infinitesimal time interval, divided by its duration $\mathrm{d}t$ (ISO 80000-3:2006, item 3-7), thus: $A = -\frac{\mathrm{d}N}{\mathrm{d}t}$	For exponential decay, $A = \lambda N$, where λ is the decay constant (item 10-26).
10-30 (*9-34*)	specific activity, massic activity *fr activité* (f) *massique*	a	$a = \frac{A}{m}$ where A is the activity (item 10-29) of a sample and m is its mass (ISO 80000-4:2006, item 4-1)	

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-26.a	second to the power minus one	s^{-1}		
10-27.a	second	s		
10-28.a	joule	J		
10-28.b	electronvolt	eV	kinetic energy acquired by an electron in passing through a potential difference of 1 V in vacuum	1 eV = 1,602 176 487(40) $\times 10^{-19}$ J [2006 CODATA recommended values].
10-29.a	becquerel	Bq	1 Bq := 1 s^{-1}	The becquerel is a special name for second to the power minus one, to be used as the coherent SI unit of activity. curie, (Ci), 1 Ci := 3,7 × 10^{10} Bq
10-30.a	becquerel per kilogram	Bq/kg		

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ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-31 (*9-35*)	activity density, volumic activity, activity concentration *fr activité* (f) *volumique*	c_A	$c_\mathrm{A} = \frac{A}{V}$ where A is the activity (item 10-29) of a sample and V is its volume (ISO 80000-3:2006, item 3-4)	
10-32 (—)	surface activity density, areic activity *fr activité* (f) *surfacique*	a_s	$a_\mathrm{s} = A/S$ where S is the total area (ISO 80000-3:2006, item 3-3) of the surface of a sample and A is its activity (item 10-29)	This value is usually defined for flat sources, where S corresponds to the total area of surface of one side of the source.
10-33 (*9-37*)	half-life *fr période* (f) *radioactive*	$T_{1/2}$	average duration (ISO 80000-3:2006, item 3-7) required for the decay of one half of the atoms or nuclei	For exponential decay, $T_{1/2} = (\ln 2)/\lambda$.
10-34 (*9-38*)	alpha disintegration energy *fr énergie* (f) *de désintégration alpha*	Q_α	sum of the kinetic energy (ISO 80000-3:2006, item 4-27.3) of the α-particle produced in the disintegration process and the recoil energy (ISO 80000-5:2007, item 5-20.1) of the product atom in the reference frame in which the emitting nucleus is at rest before its disintegration	The ground-state alpha disintegration energy, $Q_{\alpha,0}$, also includes the energy of any nuclear transitions that take place in the daughter produced.
10-35 (*9-39*)	maximum beta-particle energy *fr énergie* (f) *bêta maximale*	E_β	maximum energy (ISO 80000-5:2007, item 5-20.1) of the energy spectrum in a beta disintegration process	

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-31.a	becquerel per cubic metre	Bq/m^3		
10-32.a	becquerel per square metre	Bq/m^2		
10-33.a	second	s		
10-34.a	joule	J		
10-34.b	electronvolt	eV	See 10-28.b.	1 eV = 1,602 176 487(40) $\times 10^{-19}$ J [2006 CODATA recommended values].
10-35.a	joule	J		
10-35.b	electronvolt	eV	See 10-28.b.	1 eV = 1,602 176 487(40) $\times 10^{-19}$ J [2006 CODATA recommended values].

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ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-36 (*9-40*)	beta disintegration energy *fr* *énergie* (f) *de désintégration bêta*	Q_β	sum of the maximum beta particle kinetic energy (item 10-35) and the recoil energy (ISO 80000-5:2007, item 5-20.1) of the atom produced in the reference frame in which the emitting nucleus is at rest before its disintegration	For positron emitters, the energy for the production of an electron pair has to be added to the sum mentioned in the definition. The ground-state beta disintegration energy, $Q_{\beta,0}$, also includes the energy of any nuclear transitions that take place in the daughter product.
10-37 (*9-41*)	internal conversion factor *fr* *facteur* (m) *de conversion interne*	α	ratio of the number of internal conversion electrons to the number of gamma quanta emitted by the radioactive atom in a given transition	The quantity $\alpha/(\alpha+1)$ is also used and may be called the internal conversion fraction. Partial conversion fractions referring to the various electron shells K, L, ... are indicated by α_K, α_L, $\ldots$, $\alpha_\mathrm{K}/\alpha_\mathrm{L}$ is called the K to L internal conversion ratio.
10-38.1 (*10-1*)	reaction energy *fr* *énergie* (f) *de réaction*	Q	in a nuclear reaction, the sum of the kinetic energies (ISO 80000-4:2006, item 4-27.3) and photon energies (ISO 80000-5:2007, item 5-20.1) of the reaction products minus the sum of the kinetic and photon energies of the reactants	For exothermic nuclear reactions, $Q > 0$. For endothermic nuclear reactions, $Q < 0$.
10-38.2 (*10-2*)	resonance energy *fr* *énergie* (f) *de résonance*	E_r, E_res	kinetic energy (ISO 80000-4:2006, item 4-27.3) of an incident particle, in the reference frame of the target, corresponding to a resonance in a nuclear reaction	

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-36.a	joule	J		
10-36.b	electronvolt	eV	See 10-28.b.	1 eV = 1,602 176 487(40) × 10^{-19} J [2006 CODATA recommended values].
10-37.a	one	1		See the Introduction, 0.3.2.
10-38.a	joule	J		
10-38.b	electronvolt	eV	See 10-28.b.	1 eV = 1,602 176 487(40) × 10^{-19} J [2006 CODATA recommended values].

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-39.1 (*10-3.1*)	cross-section *fr* *section* (f) *efficace*	σ	for a specified target particle and for a specified reaction or process produced by incident charged or uncharged particles of specified type and energy, the mean number of such reactions or processes divided by the incident-particle fluence (item 10-44)	The type of process is indicated by subscripts, e.g. absorption cross-section σ_a, scattering cross-section σ_s, fission cross-section σ_f.
10-39.2 (*10-3.2*)	total cross-section *fr* *section* (f) *efficace totale*	σ_{tot}, σ_T	sum of all cross-sections (item 13-36.1) corresponding to the various reactions or processes between an incident particle of specified type and energy (ISO 80000-5:2007, item 5-20.1) and a target particle	In the case of a narrow unidirectional beam of incident particles, this is the effective cross-section for the removal of an incident particle from the beam. See the Remarks for item 10-53.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-39.a	square metre	m^2		barn (b), 1 b := 10^{-28} m^2

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-40 (*10-4*)	angular cross-section *fr* *section* (f) *efficace directionnelle*	σ_Ω	cross-section for ejecting or scattering a particle into an elementary cone, divided by the solid angle $\mathrm{d}\Omega$ (ISO 80000-3:2006, item 3-6) of that cone: $\sigma = \int \sigma_\Omega \mathrm{d}\Omega$	Quantities 10-40, 10-41 and 10-42 are sometimes called differential cross-sections. In accordance with conventions used in other parts of this International Standard, angular and spectral cross-sections are indicated by the use of subscripts. Information about incoming and outgoing particles may be added between parentheses, e.g. $\sigma_{\Omega,E}(\mathrm{n}E_0,\mathrm{p}E\vartheta)$ or $\sigma_{\Omega,E}(\mathrm{n}E_0,\mathrm{p})$ or $\sigma_{\Omega,E}(\mathrm{n},\mathrm{p})$. The cross-section for a process in which an incoming neutron of energy E_0 causes the ejection of a proton within the energy interval $[E, E+\mathrm{d}E]$ and in the elementary cone with solid angle $\mathrm{d}\Omega$, about the scattering angle ϑ, is $\sigma_{\Omega,E}(\mathrm{n}E_0,\mathrm{p}E\vartheta)\ \mathrm{d}\Omega\ \mathrm{d}E$. Sometimes, the incoming and outgoing particles are indicated by subscripts, in which case the subscript Ω or E indicating the angular or spectral character could be placed in the superscript position, e.g. $\sigma_{\mathrm{n,p}}^{\Omega,E}(E_0)$ or $\sigma_{\mathrm{n,p}}^{\Omega,E}$. If, however, the subscripts Ω or E are omitted completely from the cross-section symbol, the angular or spectral character of the cross-section then follows only from the occurrence of the variable ϑ or E for the outgoing particles between the parentheses, e.g. $\sigma_{\mathrm{n,p}}(E_0,E\vartheta)$ or $\sigma_{\mathrm{n,p}}(E\vartheta)$. These variables should then never be omitted. Instead of “spectral”, the terms “distribution with respect to energy” or “energy distribution” can be used (see ICRU Report 60, 1998).
10-41 (*10-5*)	spectral cross-section *fr* *section* (f) *efficace spectrique*	σ_E	cross-section (item 10-39.1) for a process in which the energy (ISO 80000-5:2007, item 5-20.1) of the ejected or scattered particle is in an interval of energy, divided by the range $\mathrm{d}E$ of this interval $\sigma = \int \sigma_E \mathrm{d}E$	
10-42 (*10-6*)	spectral angular cross-section *fr* *section* (f) *efficace directionnelle spectrique*	$\sigma_{\Omega,E}$	cross-section (item 10-39.1) for ejecting or scattering a particle into an elementary cone with energy E (ISO 80000-5:2007, item 5-20.1) in an energy interval, divided by the solid angle $\mathrm{d}\Omega$ (ISO 80000-3:2006, item 3-6) of that cone and the range $\mathrm{d}E$ of that interval: $\sigma = \iint \sigma_{\Omega,E} \mathrm{d}\Omega\, \mathrm{d}E$	

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-40.a	square metre per steradian	m^2/sr		
10-41.a	square metre per joule	m^2/J		
10-42.a	square metre per steradian joule	$m^2/(sr \cdot J)$		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-43.1 (*10-7.1*)	volumic cross-section, macroscopic cross-section *fr* *section* (f) *efficace macro-scopique*, *section* (f) *efficace volumique*	Σ	sum of the cross-sections (item 10-39.1) for a reaction or process of a specified type over all atoms or other entities in a given 3D domain, divided by the volume (ISO 80000-3:2006, item 3-4) of that domain	$\Sigma = n_1\sigma_1 + \ldots + n_j\sigma_j +$ where n_j is the number density and σ_j the cross-section for entities of type j. When the target particles of the medium are at rest, $\Sigma = 1/l$, where l is the mean free path (item 10-73). See the Remarks for item 10-50.
10-43.2 (*10-7.2*)	volumic total cross-section, macroscopic total cross-section *fr* *section* (f) *efficace totale macro-scopique*, *section* (f) *efficace totale volumique*	Σ_{tot}, Σ_{T}	sum of the total cross-sections (item 10-39.1) for all atoms or other entities in a given 3D domain, divided by the volume (ISO 80000-3:2006, item 3-4) of that domain	
10-44 (*10-8*)	particle fluence *fr* *fluence* (f) *de particules*	Φ	at a given point of space, the number $\mathrm{d}N$ of particles incident on a small spherical domain, divided by the cross-sectional area $\mathrm{d}A$ (ISO 80000-3:2006, item 3-3) of that domain: $\Phi = \frac{\mathrm{d}N}{\mathrm{d}A}$	The word “particle” is usually replaced by the name of a specific particle, for example *proton* fluence. When a flat source is used, for particles passing perpendicularly through the surface, this value is the number of particles passing through the surface of the flat source divided by the total area of that surface.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-43.a	metre to the power minus one	m^{-1}		
10-44.a	metre to the power minus two	m^{-2}		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-45 (*10-9*)	particle fluence rate *fr* *débit* (m) *de fluence de particules*	θ, $\dot{\Phi}$	$\theta = \frac{\mathrm{d}\Phi}{\mathrm{d}t}$ where $\mathrm{d}\Phi$ is the increment of the particle fluence (item 10-44) during an infinitesimal time interval with duration $\mathrm{d}t$ (ISO 80000-3:2006, item 3-7)	The word “particle” is usually replaced by the name of a specific particle, for example *proton* fluence rate. Mostly, symbol $\dot{\Phi}$ is used instead of θ. The distribution function expressed in terms of speed and energy, θ_v and θ_E, are related to θ by $\theta = \int \theta_v \,\mathrm{d}v = \int \theta_E \,\mathrm{d}E$. This quantity has also been termed particle flux density. Because the word “density” has several connotations, the term “fluence rate” is preferred. For a radiation field composed of particles of velocity v, the fluence rate is equal to nv, where n is the particle number density. See Remarks for 10-44.
10-46 (—)	radiant energy *fr* *énergie* (f) *rayonnante*	R	energy (ISO 80000-5:2007, item 5-20.1), excluding rest energy (item 10-3), of the particles that are emitted, transferred or received	For particles of energy E (excluding rest energy), the radiant energy, R, is equal to the product NE where N is the number of the particles that are emitted, transferred or received The distributions, N_E and R_E, of the particle number and the radiant energy with respect to energy are given by $N_E = \mathrm{d}N/\mathrm{d}E$ and $R_E = \mathrm{d}R/\mathrm{d}E$ where $\mathrm{d}N$ is the number of particles with energy between E and $E + \mathrm{d}E$, and $\mathrm{d}R$ is their radiant energy. The two distributions are related by $R_E = EN_E$.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-45.a	metre to the power minus two per second	m^{-2}/s		
10-46.a	joule	J	J	

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-47 (*10-10*)	energy fluence *fr* *fluence* (f) *énergétique*	Ψ	at a given point of space, the sum of the radiant energies $\mathrm{d}R$ (item 10-46), exclusive of rest energy, of all particles incident on a small spherical domain, divided by the cross-sectional area $\mathrm{d}A$ (ISO 80000-3:2006, item 3-3) of that domain: $\Psi = \frac{\mathrm{d}R}{\mathrm{d}A}$	
10-48 (*10-11*)	energy fluence rate *fr* *débit* (m) *de fluence énergétique*	ψ	$\psi = \frac{\mathrm{d}\Psi}{\mathrm{d}t}$ where $\mathrm{d}\Psi$ is the increment of the energy fluence (item 10-47) during an infinitesimal time interval with duration $\mathrm{d}t$ (ISO 80000-3:2006, item 3-7)	Mostly, symbol $\dot{\Psi}$ is used instead of ψ. Symbol ψ is lower case psi.
10-49 (*10-12*)	particle current *fr* *densité* (f) *de courant de particules*	$\boldsymbol{J}$, ($\boldsymbol{S}$)	vector quantity, the integral of whose normal component over any surface is equal to the net number N of particles passing through that surface in an infinitesimal time interval divided by its duration $\mathrm{d}t$ (ISO 80000-3:2006, item 3-7): $\int \boldsymbol{J} \cdot \boldsymbol{e}_\mathrm{n} \mathrm{d}A = \mathrm{d}N / \mathrm{d}t$ where $\boldsymbol{e}_\mathrm{n} \mathrm{d}A$ is the vector surface element (ISO 80000-3:2006, item 3-3)	Usually the word “particle” is replaced by the name of a specific particle, for example *proton* current. Symbol $\boldsymbol{S}$ is recommended when there is a possibility of confusion with the symbol $\boldsymbol{J}$ for electric current density. For neutron current, the symbol $\boldsymbol{J}$ is generally used. The distribution functions expressed in terms of speed and energy, $\boldsymbol{J}_v$ and $\boldsymbol{J}_E$, are related to $\boldsymbol{J}$ by $\boldsymbol{J} = \int \boldsymbol{J}_v \mathrm{d}v = \int \boldsymbol{J}_E \mathrm{d}E$.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-47.a	joule per square metre	J/m^2		
10-48.a	watt per square metre	W/m^2		
10-49.a	metre to the power minus two per second	m^{-2}/s		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-50 (*10-13*)	linear attenuation coefficient *fr coefficient* (m) *d'atténuation linéique*	μ, μ_l	$\mu = -\frac{1}{J}\frac{\mathrm{d}J}{\mathrm{d}x}$ where J is magnitude of the current rate (item 10-49) of a beam of particles parallel to the x-direction	μ is equal to the macroscopic total cross-section Σ_{tot} for the removal of particles from the beam.
10-51 (*10-14*)	mass attenuation coefficient *fr coefficient* (m) *d'atténuation massique*	μ_m	$\mu_m = \mu / \rho$ where μ is the linear attenuation coefficient (item 10-50) and ρ is the mass density (ISO 80000-4:2006, item 4-2) of the medium	
10-52 (*10-15*)	molar attenuation coefficient *fr coefficient* (m) *d'atténuation molaire*	μ_c	$\mu_c = \mu / c$ where μ is the linear attenuation coefficient (item 10-50) and c is the amount-of-substance concentration (ISO 80000-9:2009, item 9-13) of the medium	
10-53 (*10-16*)	atomic attenuation coefficient *fr coefficient* (m) *d'atténuation atomique*	μ_{a}	$\mu_{\mathrm{a}} = \mu / n$ where μ is the linear attenuation coefficient (item 10-50) and n is the number density (ISO 80000-9:2009, item 9-10.1) of the atoms in the substance	μ is equal to the total cross-section σ_{tot} for the removal of particles from the beam. See also item 10-39.2.
10-54 (*10-17*)	half-value thickness *fr épaisseur* (f) *de demi-atténuation*	$d_{1/2}$	thickness (ISO 80000-3:2006, item 3-1.4) of the attenuating layer that reduces the quantity of interest of a unidirectional beam to half of its initial value	For exponential attenuation, $d_{1/2} = (\ln 2)/\mu$. Other half-value thicknesses, such as those for attenuation, exposure and air kerma are also used.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-50.a	metre to the power minus one	m^{-1}		
10-51.a	metre squared per kilogram	m^2/kg		
10-52.a	metre squared per mol	m^2/mol		
10-53.a	metre squared	m^2		
10-54.a	metre	m		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-55 (*10-18*)	total linear stopping power *fr pouvoir* (m) *d'arrêt linéique total*	S, S_l	$S = -\mathrm{d}E/\mathrm{d}x$ where $-\mathrm{d}E$ is the energy (ISO 80000-5:2007, item 5-20.1) decrement in the x-direction along an elementary path with the length $\mathrm{d}x$ (ISO 80000-3:2006, item 3-1.1)	Also called stopping power. Both electronic losses and radiative losses are included. The ratio of the total linear stopping power of a substance to that of a reference substance is called the relative linear stopping power. See also item 10-88.
10-56 (*10-19*)	total atomic stopping power *fr pouvoir* (m) *d'arrêt atomique total*	S_a	$S_\mathrm{a} = S/n$ where S is the total linear stopping power (item 10-55) and n is the number density (ISO 80000-9:2009, item 9-10.1) of the atoms in the substance	
10-57 (*10-20*)	total mass stopping power *fr pouvoir* (m) *d'arrêt massique total*	S_m	$S_m = S/\rho$ where S is the total linear stopping power (item 10-55) and ρ is the mass density (ISO 80000-4:2006, item 4-2) of the sample	The ratio of the total mass stopping power of a substance to that of a reference substance is called the relative mass stopping power.
10-58 (*10-21*)	mean linear range *fr parcours* (m) *moyen linéaire*	R, R_l	mean total rectified path length (ISO 80000-3:2006, item 3-1.1) travelled by a particle in the course of slowing down to rest (or to some suitable cut-off energy) in a given substance under specified conditions averaged over a group of particles having the same initial energy (ISO 80000-5:2007, item 5-20.1)	
10-59 (*10-22*)	mean mass range *fr parcours* (m) *moyen en masse*	R_ρ, (R_m)	$R_\rho = R\rho$ where R is the mean linear range (item 10-58) and ρ is the mass density (ISO 80000-4:2006, item 4-2) of the sample	

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-55.a	joule per metre	J/m		
10-55.b	electronvolt per metre	eV/m		1 eV/m = 1,602 176 487 (40) $\times 10^{-19}$ J/m [2006 CODATA recommended values].
10-56.a	joule metre squared	$J \cdot m^2$		
10-56.b	electronvolt metre squared	$eV \cdot m^2$		1 $eV \cdot m^2$ = 1,602 176 487 (40) $\times 10^{-19}$ $J \cdot m^2$ [2006 CODATA recommended values].
10-57.a	joule metre squared per kilogram	$J \cdot m^2/kg$		
10-57.b	electronvolt metre squared per kilogram	$eV \cdot m^2/kg$		1 $eV \cdot m^2/kg$ = 1,602 176 487(40) $\times 10^{-19}$ $J \cdot m^2/kg$ [2006 CODATA recommended values].
10-58.a	metre	m		
10-59.a	kilogram per metre squared	kg/m^2		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-60 (*10-23*)	linear ionization *fr ionisation* (f) *linéique*	N_{il}	$N_{il} = \frac{1}{e}\frac{\mathrm{d}Q}{\mathrm{d}l}$ where e is the elementary charge and $\mathrm{d}Q$ is the average total charge of all positive ions produced over an infinitesimal element of the path with length $\mathrm{d}l$ (ISO 80000-3:2006, item 3-1.1) by an ionizing charged particle	Ionization due to secondary ionizing particles, etc., is included.
10-61 (*10-24*)	total ionization *fr ionisation* (f) *totale*	N_i	by a particle, total mean charge, divided by the elementary charge, e, of all positive ions produced by an ionizing charged particle along its entire path and along the paths of any secondary charged particles	$N = \int N_\mathrm{i}\,\mathrm{d}l$ See Remarks for item 10-60.
10-62 (*10-25*)	average energy loss per elementary charge produced *fr perte* (f) *moyenne d'énergie par paire d'ions formée*	W_i	$W_\mathrm{i} = E_\mathrm{k} / N_\mathrm{i}$ where E_k is the initial kinetic energy (ISO 80000-4:2006, item 4-27.3) of an ionizing charged particle and N_i is the total ionization (item 10-61) produced by that particle	The name “average energy loss per ion pair formed” is usually used, although it is ambiguous.The quantity $S_\mathrm{i} / N_\mathrm{i}$, sometimes called the average energy per ion pair formed, should not be confused with W_i. In ICRU Report 60, the mean energy expended in a gas per ion pair formed, W, is the quotient of E by N, where N is the mean number of ion pairs formed when the initial kinetic energy E of a charged particle is completely dissipated in the gas. Thus $W = E/N$ where the mean number N of ion pairs is equal to the total liberated charge of either sign divided by the charge of the electron. It follows from the definition of W that the ions produced by bremsstrahlung or other secondary radiation emitted by the charged particles are included in N.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-60.a	metre to the power minus one	m^{-1}		
10-61.a	one	1		See the Introduction, 0.3.2.
10-62.a	joule	J		
10-62.b	electronvolt	eV	See 10-28.b.	1 eV = 1,602 176 487(40) × 10^{-19} J [2006 CODATA recommended values].

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-63 (*10-26*)	mobility *fr mobilité* (f)	μ	average drift speed (ISO 80000-3:2006, item 3-8.1) imparted to a charged particle in a medium by an electric field, divided by the electric field strength (IEC 80000-6:2008, item 6-10)	
10-64.1 (*10-29*)	particle number density *fr nombre* (m) *volumique de particules*	n	$n = N/V$ where N is the number of particles in the 3D domain with the volume V	n is the general symbol for the number density of particles. The distribution function expressed in terms of speed and energy, n_v and n_E, is related to n by $n = \int n_v \mathrm{d}v = \int n_E \mathrm{d}E$. The word “particle” is usually replaced by the name of a specific particle, for example *neutron* number density.
10-64.2 (*10-27*)	ion number density, ion density *fr nombre* (m) *volumique d'ions*	n^+, n^-	$n^+ = N^+/V$, $n^- = N^-/V$ where N^+ and N^- are the number of positive and negative ions, respectively, in a 3D domain with volume V (ISO 80000-3:2006, item 3-4)	
10-65 (*10-28*)	recombination coefficient, recombination factor *fr coefficient* (m) *de recombinaison*	α	coefficient in the law of recombination $-\frac{\mathrm{d}n^+}{\mathrm{d}t} = -\frac{\mathrm{d}n^-}{\mathrm{d}t} = \alpha n^+ n^-$ where n^+ and n^- are the ion number densities (item 10-64.2) of positive and negative ions, respectively, recombined during an infinitesimal time interval with duration $\mathrm{d}t$ (ISO 80000-3:2006, item 3-7)	The widely used term “recombination factor” is not correct because “factor” should only be used for quantities with dimension 1.
10-66 (*10-32*)	diffusion coefficient, diffusion coefficient for particle number density *fr coefficient* (m) *de diffusion, coefficient* (m) *de diffusion pour le nombre volumique de particules*	D, D_n	in the x-direction, $D_n = -\frac{J_x}{\partial n / \partial x}$ where J_x is the x-component of the particle current (item 10-49) and n is the particle number density (item 10-64.1)	The word “particle” is usually replaced by the name of a specific particle, for example *neutron* number density. For a particle of a given speed v, $D_n(v) = -\frac{J_{v,x}}{\partial n_v / \partial x}$.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-63.a	square metre per volt second	$m^2/(V \cdot s)$		
10-64.a	metre to the power minus three	m^{-3}		
10-65.a	cubic metre per second	m^3/s		
10-66.a	metre squared per second	m^2/s		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-67 (*10-33*)	diffusion coefficient for fluence rate *fr coefficient* (m) *de diffusion pour le débit de fluence*	D_φ, (D)	$D_\varphi = -\frac{J_x}{\partial\varphi/\partial x}$ where J_x is the x-component of the particle current (item 10-49) and φ is the particle fluence rate (item 10-45)	For a particle of a given speed v, $D_\varphi(v) = -\frac{J_{v,x}}{\partial\varphi_v/\partial x}$ and $vD_\varphi(v) = -D_n(v)$.
10-68 (*10-34*)	particle source density *fr densité* (f) *totale d'une source de particules*	S	rate of production of particles in a 3D domain divided by the volume (ISO 80000-3:2006, item 3-4) of that element	The word "particle" is usually replaced by the name of a specific particle, for example *proton* source density. The distribution functions expressed in terms of speed and energy, S_v and S_E, are related to S by $S = \int S_v \mathrm{d}v = \int S_E \mathrm{d}E$.
10-69 (*10-35*)	slowing-down density *fr densité* (f) *de ralentissement*	q	number density (item 10-64.1) slowing down past a given energy (ISO 80000-5:2007, item 5-20.1) value in an infinitesimal time interval, divided by the duration (ISO 80000-3:2006, item 3-7) of that interval	For a number density n and duration $\mathrm{d}t$, $q = -\frac{\mathrm{d}n}{\mathrm{d}t}$.
10-70 (*10-36*)	resonance escape probability *fr facteur* (m) *antitrappe*	p	in an infinite medium, the probability that a neutron slowing down will traverse all or some specified portion of the range of resonance energies (item 10-38.2) without being absorbed	
10-71 (*10-37*)	lethargy *fr léthargie* (f)	u	for a neutron of kinetic energy E (ISO 80000-4:2006, item 4-27.3), $u = \ln(E_0/E)$ where E_0 is a reference energy	

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-67.a	metre	m		
10-68.a	second to the power minus one per cubic metre	s^{-1}/m^3		
10-69.a	metre to the power minus three per second	m^{-3}/s		
10-70.a	one	1		See the Introduction, 0.3.2.
10-71.a	one	1		See the Introduction, 0.3.2.

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-72 (*10-38*)	average logarithmic energy decrement *fr* *décrément* (m) *logarithmique moyen de l'énergie*, *paramètre* (m) *de ralentis-sement*	ξ	average value of the increase in lethargy (item 10-71) in elastic collisions between neutrons and nuclei whose kinetic energy (ISO 80000-4:2006, item 4-27.3) is negligible compared with that of the neutrons	
10-73 (*10-39*)	mean free path *fr* *libre parcours* (m) *moyen*	l, λ	average distance (ISO 80000-3:2006, item 3-1.9) that particles travel between two successive specified reactions or processes	See the Remarks for item 10-43.
10-74.1 (*10-40.1*)	slowing-down area *fr* *aire* (f) *de ralentis-sement*	L_s^2, L_sl^2	in an infinite homogenous medium, one-sixth of the mean square distance (ISO 80000-3:2006, item 3-1.9) between the neutron source and the point where a neutron reaches a given energy (ISO 80000-5:2007, item 5-20.1)	
10-74.2 (*10-40.2*)	diffusion area *fr* *aire* (f) *de diffusion*	L^2	in an infinite homogenous medium, one-sixth of the mean square distance (ISO 80000-3:2006, item 3-1.9) between the point where a neutron enters a specified class and the point where it leaves this class	The class of neutrons must be specified.
10-74.3 (*10-40.3*)	migration area *fr* *aire* (f) *de migration*	M^2	sum of the slowing-down area (ISO 80000-3:2006, item 3-3) from fission energy to thermal energy (ISO 80000-5:2007, item 5-20.1) and the diffusion area for thermal neutrons	

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-72.a	one	1		See the Introduction, 0.3.2.
10-73.a	metre	m		
10-74.a	metre squared	m^2		

(continued)

ATOMIC AND NUCLEAR PHYSICS				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-75.1 (*10-41.1*)	slowing-down length *fr* *longueur* (f) *de ralentissement*	L_s, L_{sl}	$L_s = \sqrt{L_s^2}$ where L_s^2 is the slowing-down area (item 10-74.1)	
10-75.2 (*10-41.2*)	diffusion length *fr* *longueur* (f) *de diffusion*	L	$L = \sqrt{L^2}$ where L^2 is the diffusion area (item 10-74.2)	
10-75.3 (*10-41.3*)	migration length *fr* *longueur* (f) *de migration*	M	$M = \sqrt{M^2}$ where M^2 is the migration area (item 10-74.3)	
10-76.1 (*10-42.1*)	neutron yield per fission *fr* *nombre* (m) *de neutrons produits par fission*	ν	average number of fission neutrons, both prompt and delayed, emitted per fission event	Also called ν-factor and η-factor.
10-76.2 (*10-42.2*)	neutron yield per absorption *fr* *nombre* (m) *de neutrons produits par neutron absorbé*	η	average number of fission neutrons, both prompt and delayed, emitted per neutron absorbed in a fissionable nuclide or in a nuclear fuel, as specified	ν/η is equal to the ratio of the macroscopic cross-section for fission to that for absorption, both for neutrons in the fuel material.
10-77 (*10-43*)	fast fission factor *fr* *facteur* (m) *de fission rapide*	φ	in an infinite medium, the ratio of the mean number of neutrons produced by fission due to neutrons of all energies (ISO 80000-5:2007, item 5-20.1), to the mean number of neutrons produced by fissions due to thermal neutrons only	The class (thermal) of neutrons must be specified.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-75.a	metre	m		
10-76.a	one	1		See the Introduction, 0.3.2.
10-77.a	one	1		See the Introduction, 0.3.2.

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ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-78 (*10-44*)	thermal utilisation factor *fr* *facteur* (m) *d'utilisation thermique*	f	in an infinite medium, the ratio of the number of thermal neutrons absorbed in a fissionable nuclide or in a nuclear fuel, as specified, to the total number of thermal neutrons absorbed	The class (thermal) of neutrons must be specified.
10-79 (*10-45*)	non-leakage probability *fr* *probabilité* (f) *de non-fuite*	Λ	probability that a neutron will not escape from the reactor during the slowing-down process or while it diffuses as a thermal neutron	The class (thermal) of neutrons must be specified.
10-80.1 (*10-46.1*)	multiplication factor *fr* *facteur* (m) *de multiplication*	k	ratio of the total number of fission or fission-dependent neutrons produced in a time interval to the total number of neutrons lost by absorption and leakage during the same interval	
10-80.2 (*10-46.2*)	infinite multiplication factor *fr* *facteur* (m) *de multiplication infini*	k_∞	multiplication factor (item 10-80.1) for an infinite medium or for an infinite repeating lattice	For a thermal reactor, $k_\infty = \eta \varepsilon p f$.
10-80.3 (*10-46.3*)	effective multiplication factor *fr* *facteur* (m) *de multiplication effectif*	k_{eff}	multiplication factor for a finite medium	$k_{\mathrm{eff}} = k_\infty \Lambda$.
10-81 (*10-47*)	reactivity *fr* *réactivité* (f)	ρ	$\rho = \frac{k_{\mathrm{eff}} - 1}{k_{\mathrm{eff}}}$ where k_{eff} is effective multiplication factor (item 10-80.3)	

UNITS				ATOMIC AND NUCLEAR PHYSICS
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-78.a	one	1		See the Introduction, 0.3.2.
10-79.a	one	1		See the Introduction, 0.3.2.
10-80.a	one	1		See the Introduction, 0.3.2.
10-81.a	one	1		See the Introduction, 0.3.2.

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-82 (*10-48*)	reactor time constant *fr constante* (f) *de temps du réacteur*	T	duration (ISO 80000-3:2006, item 3-7) required for the neutron fluence rate (item 10-45) in a reactor to change by the factor e when the fluence rate is rising or falling exponentially	Also called reactor period.
10-83.1 (*10-50.1*)	energy imparted *fr énergie* (f) *commu-niquée*	ε	for ionizing radiation in the matter in a given 3D domain, $\varepsilon = \sum_i \varepsilon_i$ where the energy deposit, ε_i, is the energy (ISO 80000-5:2007, item 5-20.1) deposited in a single interaction i, and is given by $\varepsilon_i = \varepsilon_{\text{in}} - \varepsilon_{\text{out}} + Q$, where ε_{in} is the energy (ISO 80000-5:2007, item 5-20.1) of the incident ionizing particle, excluding rest energy (item 10-3), ε_{out} is the sum of the energies (ISO 80000-5:2007, item 5-20.1) of all ionizing particles leaving the interaction, excluding rest energy (item 10-3), and Q is the change in the rest energies (item 10-3) of the nucleus and of all particles involved in the interaction	Energy imparted is a stochastic quantity.
10-83.2 (*10-50.2*)	mean energy imparted *fr énergie* (f) *commu-niquée moyenne*	$\bar{\varepsilon}$	to the matter in a given domain, $\bar{\varepsilon} = R_{\text{in}} - R_{\text{out}} + \sum Q$ where R_{in} is the radiant energy (item 10-46) of all those charged and uncharged ionizing particles that enter the domain, R_{out} is the radiant energy of all those charged and uncharged ionizing particles that leave the domain, and $\sum Q$ is the sum of all changes of the rest energy (item 10-3) of nuclei and elementary particles that occur in that domain	This quantity has the meaning of the expected value of the energy imparted (item 10-83.1). Sometimes, it has been called the integral absorbed dose. $Q > 0$ means decrease of rest energy; $Q < 0$ means increase of rest energy.

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-82.a	second	s		
10-83.a	joule	J		

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-84.1 (*10-51.2*)	absorbed dose *fr dose* (f) *absorbée*	D	for any ionizing radiation, $D = \frac{\mathrm{d}\bar{\varepsilon}}{\mathrm{d}m}$ where $\mathrm{d}\bar{\varepsilon}$ is the mean energy imparted (item 10-83.2) by ionizing radiation to an element of irradiated matter with the mass $\mathrm{d}m$ (ISO 80000-4:2006, item 4-1)	$\bar{\varepsilon} = \int D\mathrm{d}m$ where $\mathrm{d}m$ is the element of mass of the irradiated matter. In the limit of a small domain, the mean specific energy $\bar{z}$ is equal to the absorbed dose D.
10-84.2 (*10-51.1*)	specific energy imparted *fr énergie* (f) *communiquée massique*	z	for any ionizing radiation, $z = \frac{\varepsilon}{m}$ where ε is the energy imparted (item 10-83.1) to irradiated matter and m is the mass (ISO 80000-4:2006, item 4-1) of that matter	z is a stochastic quantity. In the limit of a small domain, the mean specific energy $\bar{z}$ is equal to the absorbed dose D. The specific energy imparted can be due to one or more (energy-deposition) events.
10-85	quality factor *fr facteur* (m) *de qualité*	Q	factor in the calculation and measurement of dose equivalent (item 10-86), by which the absorbed dose (item 10-84.1) is to be weighted in order to account for different biological effectiveness of radiations, for radiation protection purposes	Q is determined by the unrestricted linear energy transfer, L_∞ (often denoted as L or LET), of charged particles passing through a small volume element at this point (the value of L_∞ is given for charged particles in water, not in tissue; the difference, however, is small).
10-86 (*10-52*)	dose equivalent *fr dose* (f) *équivalente*, [*équivalent* (m) *de dose*]	H	at the point of interest in tissue, $H = DQ$ where D is the absorbed dose (item 10-84.1) and Q is the quality factor (item 10-85) at that point	The dose equivalent at a point in tissue is given by $H = \int_0^\infty Q(L) D_L \mathrm{d}L$ where $D_L = \mathrm{d}D/\mathrm{d}L$ is the distribution of L of the absorbed dose at the point of interest. The relationship of L is given in ICRP Publication 103 (ICRP, 2007).

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-84.a	gray	Gy	1 Gy := 1 J/kg	The gray is a special name for joule per kilogram, to be used as the coherent SI unit for these quantities. rad (rad), 1 rad := 10^{-2} Gy
10-85.a	one	1		
10-86.a	sievert	Sv	1 Sv := 1 J/kg	The sievert is a special name for joule per kilogram, to be used as the coherent SI unit for dose equivalent. rem (rem), 1 rem := 10^{-2} Sv

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-87 (*10-53*)	absorbed dose rate *fr* *débit* (m) *de dose absorbée*	$\dot{D}$	$\dot{D} = \frac{\mathrm{d}D}{\mathrm{d}t}$ where $\mathrm{d}D$ is the increment of absorbed dose (item 10-84.1) during time interval with duration $\mathrm{d}t$ (ISO 80000-3:2006, item 3-7)	
10-88 (*10-54*)	linear energy transfer *fr* *transfert* (m) *linéique d'énergie*	L_Δ	for ionizing charged particles, $L_\Delta = \frac{\mathrm{d}E_\Delta}{\mathrm{d}l}$ where $\mathrm{d}E_\Delta$ is the mean energy lost in electronic collisions locally to matter along a small path through the matter, minus the sum of the kinetic energies of all the electrons released with kinetic energies in excess of Δ, and $\mathrm{d}l$ (ISO 80000-3:2006, item 3-1.1) is the length of that path	This quantity is not completely defined unless Δ is specified, i.e. the maximum kinetic energy of secondary electrons whose energy is considered to be "locally deposited." Δ may be expressed in eV. Linear energy transfer is often abbreviated to LET, but the subscript Δ or its numerical value should be appended to it.
10-89 (*10-55*)	kerma *fr* *kerma* (m)	K	for indirectly ionizing (uncharged) particles, $K = \frac{\mathrm{d}E_{\mathrm{tr}}}{\mathrm{d}m}$ where $\mathrm{d}E_{\mathrm{tr}}$ is the mean sum of the initial kinetic energies (ISO 80000-4:2006, item 4-27.3) of all the charged ionizing particles liberated by uncharged ionizing particles in an element of matter, and $\mathrm{d}m$ is the mass (ISO 80000-4:2006, item 4-1) of that element	The name "kerma" is derived from Kinetic Energy Released in MAtter (or MAss or MAterial). The quantity $\mathrm{d}E_{\mathrm{tr}}$ includes the kinetic energy of the charged particles emitted in the decay of excited atoms or molecules or nuclei.
10-90 (*10-56*)	kerma rate *fr* *débit* (m) *de kerma*	$\dot{K}$	$\dot{K} = \frac{\mathrm{d}K}{\mathrm{d}t}$ where K is the increment of kerma (item 10-89) during time interval with duration t (ISO 80000-3:2006, item 3-7)	

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-87.a	gray per second	Gy/s		1 Gy/s = 1 W/kg See the Remarks for item 10-84.a.
10-88.a	joule per metre	J/m		
10-88.b	electronvolt per metre	eV/m		1 eV/m = 1,602 176 487(40) $\times$ 10^{-19} J [2006 CODATA recommended values].
10-89.a	gray	Gy		See the Remarks for item 10-84.a.
10-90.a	gray per second	Gy/s		1 Gy/s = 1 W/kg See the Remarks for item 10-84.a.

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-91 (*10-57*)	mass energy transfer coefficient *fr* *coefficient* (m) *de transfert d'énergie massique*	μ_{tr}/ρ	for a beam of indirectly ionizing uncharged particles acting on the material, $\mu_{\mathrm{tr}}/\rho = \frac{1}{\rho}\frac{1}{R}\frac{\mathrm{d}R_{\mathrm{tr}}}{\mathrm{d}l}$ where $\mathrm{d}R_{\mathrm{tr}}$ is the mean energy that is transferred to kinetic energy of charged particles by interactions of the incident radiation R in traversing a distance $\mathrm{d}l$ in the material of density ρ	$\mu_{\mathrm{tr}}/\rho = \dot{K}/\psi$, where $\dot{K}$ is the kerma rate (item 10-90) and ψ is the energy fluence rate (item 10-48). The quantity $\mu_{\mathrm{en}}/\rho = (\mu_{\mathrm{tr}}/\rho)(1-g)$ (where g is the fraction of the kinetic energy of the liberated charged particles that is lost in radiative processes in the material) is called the mass energy absorption coefficient. The mass energy absorption coefficient of a compound material depends on the stopping power of the material. Thus its evaluation cannot, in principle, be reduced to a simple summation of the mass energy absorption coefficient of the atomic constituents. Such a summation can provide an adequate approximation when the value of g is sufficiently small. See also item 10-51.
10-92 (*10-58*)	exposure *fr* *exposition* (f)	X	for X- or gamma radiation, $X = \frac{\mathrm{d}Q}{\mathrm{d}m}$ where $\mathrm{d}Q$ is the absolute value of the mean total electric charge of the ions of the same sign produced in dry air when all the electrons and positrons liberated or created by photons in an element of air are completely stopped in air, and $\mathrm{d}m$ is the mass (ISO 80000-4:2006, item 4-1) of that element	The ionization produced by electrons emitted in atomic or molecular relaxation is included in $\mathrm{d}Q$. The ionization due to photons emitted by radiative processes (i.e. bremsstrahlung and fluorescence photons) is not to be included in $\mathrm{d}Q$. This quantity should not be confused with the quantity photon exposure (ISO 80000-7:2008, item 7-51), radiation exposure (ISO 80000-7:2008, item 7-18) or the quantity luminous exposure (ISO 80000-7:2008, item 7-39).

UNITS				ATOMIC AND NUCLEAR PHYSICS
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-91.a	square metre per kilogram	m^2/kg		
10-92.a	coulomb per kilogram	C/kg		röntgen (R), 1 R := 2,58 × 10^{-4} C/kg

(continued)

ATOMIC AND NUCLEAR PHYSICS				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
10-93 (*10-59*)	exposure rate *fr* *débit* (m) *d'exposition*	$\dot{X}$	$\dot{X} = \frac{\mathrm{d}X}{\mathrm{d}t}$ where $\mathrm{d}X$ is the increment of exposure (item 10-92) during time interval with duration $\mathrm{d}t$ (ISO 80000-3:2006, item 3-7)	

UNITS				**ATOMIC AND NUCLEAR PHYSICS**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
10-93.a	coulomb per kilogram second	C/(kg · s)		1 C/(kg · s) = 1 A/kg

(concluded)

Annex A
(informative)

Non-SI units used in atomic and nuclear physics

Quantity	Name of unit	Symbol for unit	Value in SI units
		Units accepted for use with the SI	
energy	electronvolt	eV	1 eV = 1,602 176 487 (40) · 10^{-19} J
mass	dalton	Da	1 Da = 1,660 538 782 (83) · 10^{-27} kg
	unified atomic mass unit	u	1 u = 1 Da
length	astronomical unit	ua	1 ua = 1,495 978 706 91 (6) · 10^{11} m
		Natural units (n.u.)	
speed	n.u. of speed (speed of light in vacuum)	c_0	299 792 458 m/s (exact)
action	n.u. of action (reduced Planck constant)	$\hbar$	1,054 571 628 (53) · 10^{-34} J s
mass	n.u. of mass (electron mass)	m_e	9,109 382 15 (45) · 10^{-31} kg
time	n.u. of time	$\hbar/(m_\mathrm{e}c_0^2)$	1,288 088 6570 (18) · 10^{-21} s
		Atomic units (a.u.)	
charge	a.u. of charge (elementary charge)	e	1,602 176 487 (40) · 10^{-19} C
mass	a.u. of mass (electron mass)	m_e	9,109 382 15 (45) · 10^{-31} kg
action	a.u. of action (reduced Planck constant)	$\hbar$	1,054 571 628 (53) · 10^{-34} J s
length	a.u. of length, bohr (Bohr radius)	a_0	0,529 177 208 59 (36) · 10^{-10} m
energy	a.u. of energy, hartree (Hartree energy)	E_h	4,359 743 94 (22) · 10^{-18} J
time	a.u. of time	$\hbar/E_\mathrm{h}$	2,418 884 326 505 (16) · 10^{-17} s

NOTE The units in this annex are those given in Table 7 in the 8th edition (2006) of BIPM's SI Brochure. For completeness, the astronomical unit of length is included.

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